MI RF UPGRADE – DUAL PA's

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Outline

- Summary of RF System Parameters
- Advantages of Two PA Approach
- Disadvantages of Two PA Approach
- Modifications Required to Existing 53 MHz System
- R&D
- Conclusion

RF System Requirements

	Present Main Injector Operation	Upgraded Main Injector - Base	Upgraded Main Injector - Max
		Modified Existing Cavity	Modified Existing Cavity
Harmonic number:	588	588	588
Number of filled buckets:	504	504	504
Frequency:	52.813 – 53.104 MHz	52.813 – 53.104 MHz	52.813 – 53.104 MHz
Acceleration ramp slope:	205 Gev/s	280 Gev/s	280 Gev/s
V x (Sin φ_s):	2.27 x 10^6 volts / turn	3.10 x 10^6 volts / turn	3.10 x 10^6 volts / turn
Beam intensity:	3.0x10^{13} protons	3.5x10^{13} protons	7.0x10^{13} protons
Power to beam:	0.984 Megawatts	1.57 Megawatts	3.14 Megawatts
Number of cavities:	18	18	18
Cavity R/Q:	104	104	104
Accelerating power per cavity (beam):	54.7 Kilowatts / Cavity	87.2 Kilowatts / Cavity	174.4 Kilowatts / Cavity
Accelerating power per cavity (beam + cavity):	113.6 Kilowatts / Cavity	174.5 Kilowatts / Cavity	349 Kilowatts / Cavity
Maximum cavity accelerating voltage:	240 Kilovolts / Cavity	240 Kilovolts / Cavity	240 Kilovolts / Cavity
Total accelerating voltage available:	4.32 Megavolts	4.32 Megavolts	4.32 Megavolts
Total Power required (beam + cavity):	~ 2.045 Megawatts	~ 3.14 Megawatts	~ 6.28 Megawatts

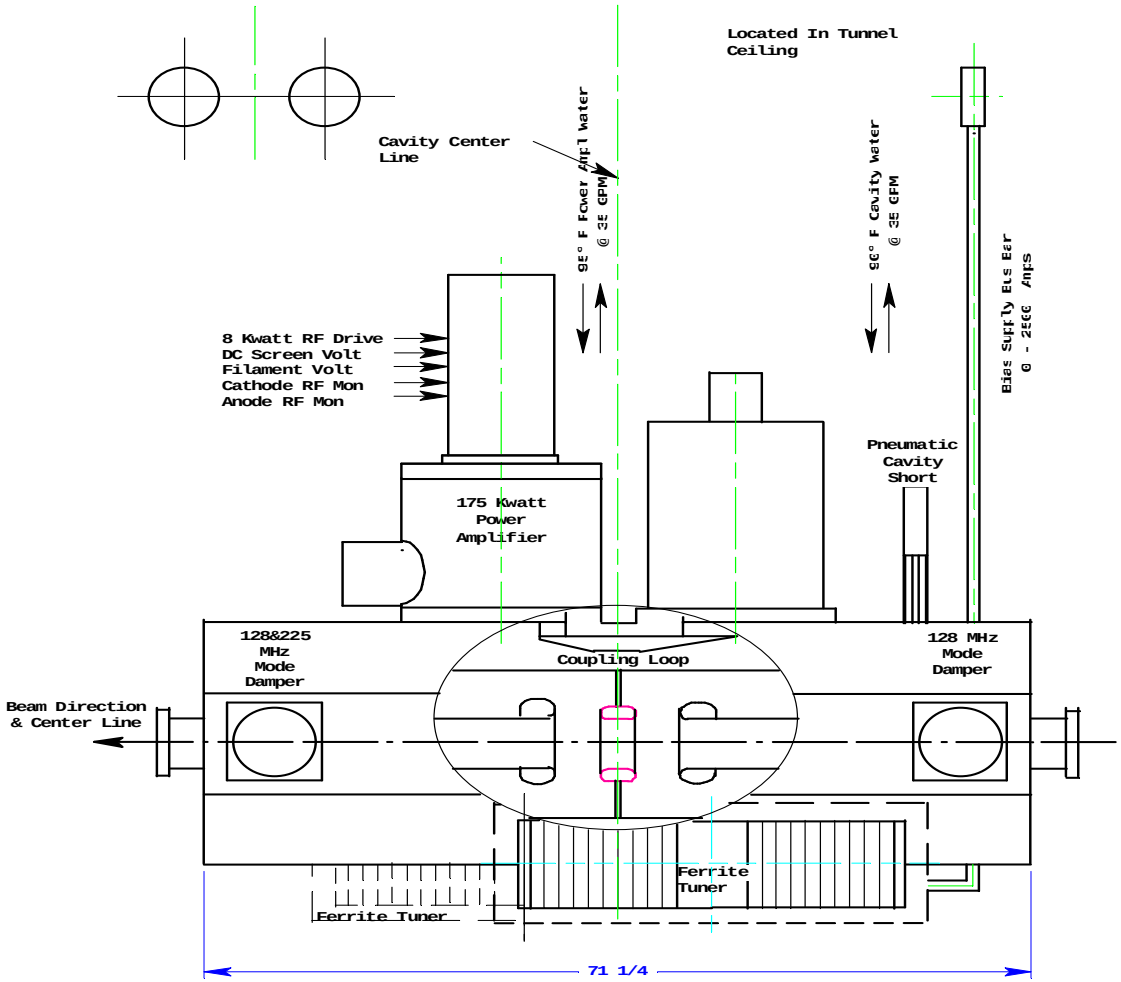
Advantages of Two PA's

- Will double the available current.
- Could accelerate up to ~ $1x10^{14}$ protons, not considering stability issues.
- With added external cavity load (Robinson stability), for beam power equal to cavity power, could accelerate ~ $8x10^{13}$ protons (88% of amplifier capability).
- Prototype system currently under fabrication.
- Minimum design required, prototype can use existing parts for proof of operation.
- Install a prototype system in MI by Fall 2005.

Disadvantages of Two PA's

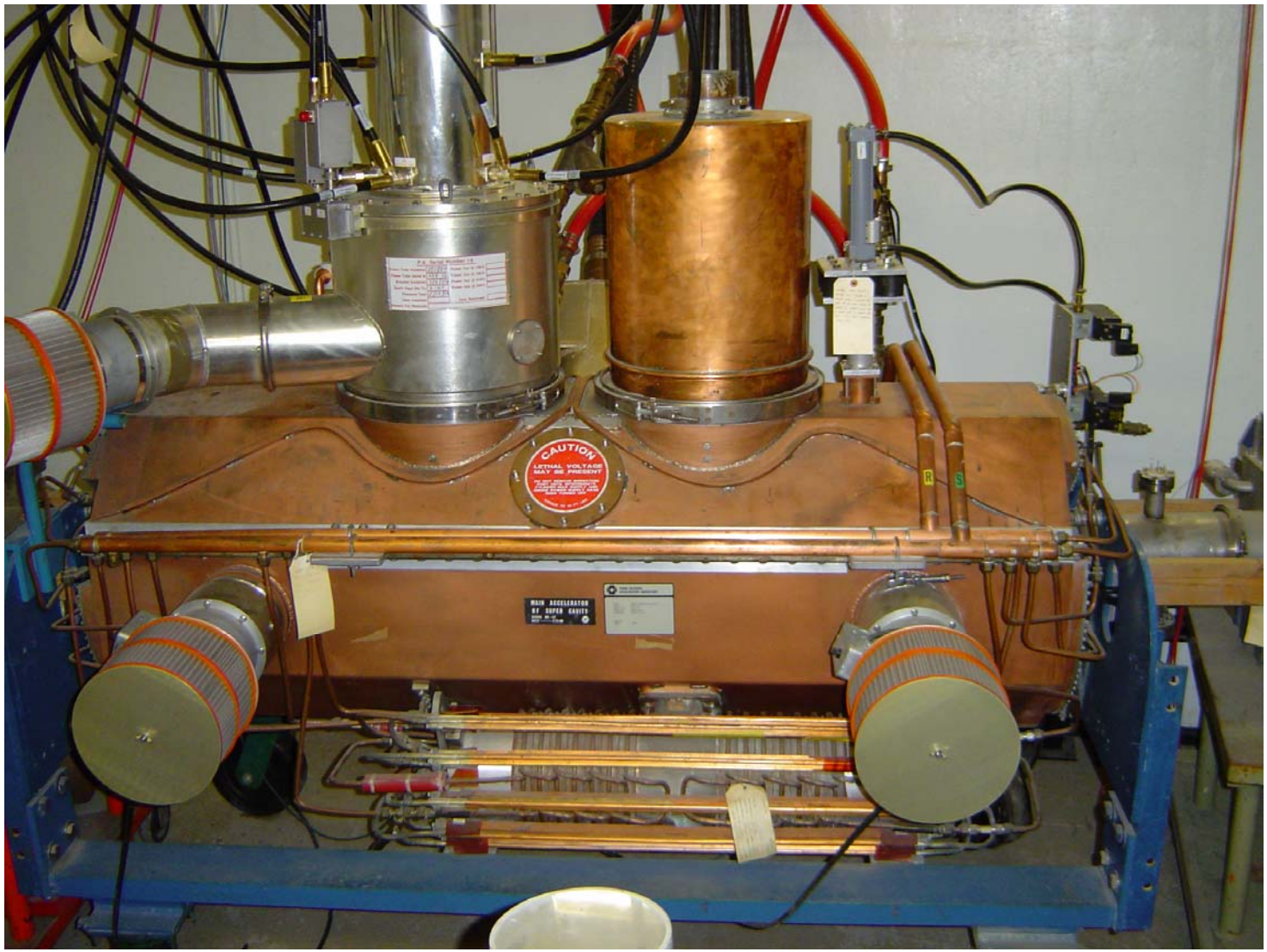
- Does not increase cavity voltage, only available current.
- To increase voltage, we will need to add cavities (only 21 rf cavities exist, 18 installed).
- Transient beam loading will be challenging at these intensities, especially during beam gymnastics.
- May need to dissipate additional cavity power for Robinson stability, feedback & feed forward may not be completely sufficient.

Standard MI RF Cavity

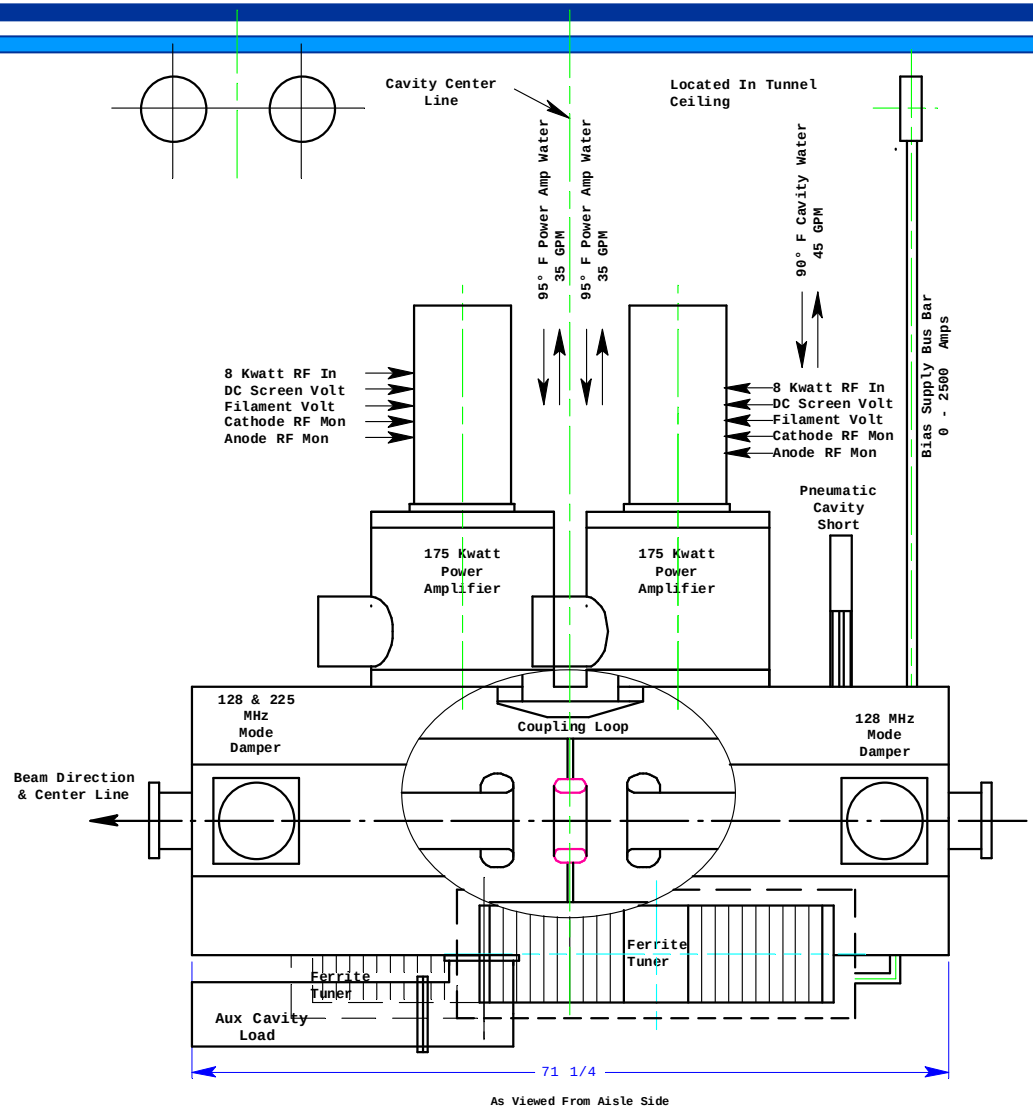


Present Main Injector Cavity

Standard MI RF Cavity



Modified MI RF Cavity



Modified Main Injector Cavity for Two Power Amplifiers

Cavity Issues

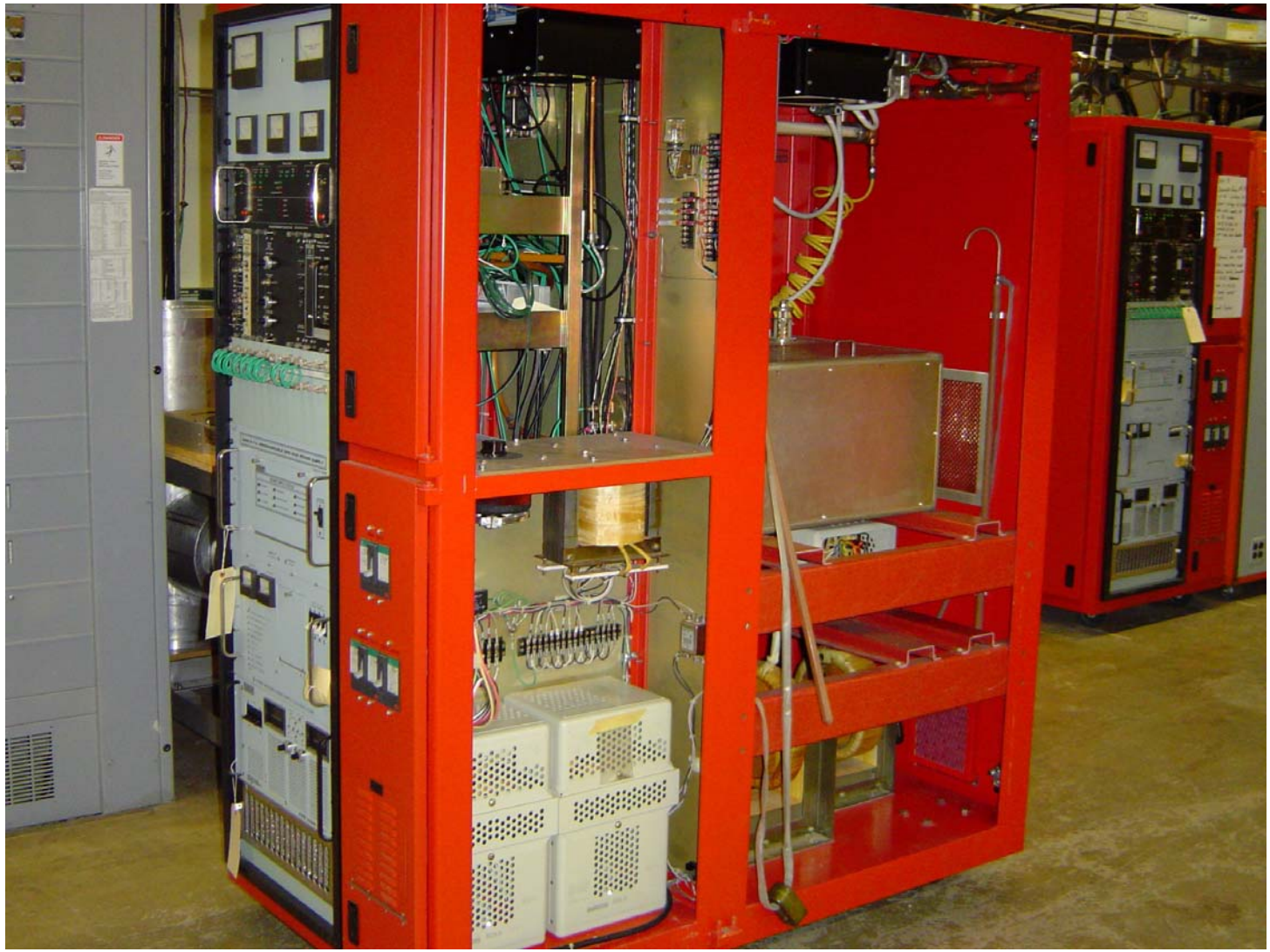
- Modifications
  - Fabricate new rf coupling loop for two PA operation
    - Prototype loop is fabricated and ready for testing.
    - Measure spurious modes, coupling ratio (step-up ratio) , cavity tuning range.
  - Implement optional external rf loading to cavity.
- Lifetime issues
  - Cavities are 35 years old, water leaks are the biggest concern.

Coupling Loop for 2 PA's

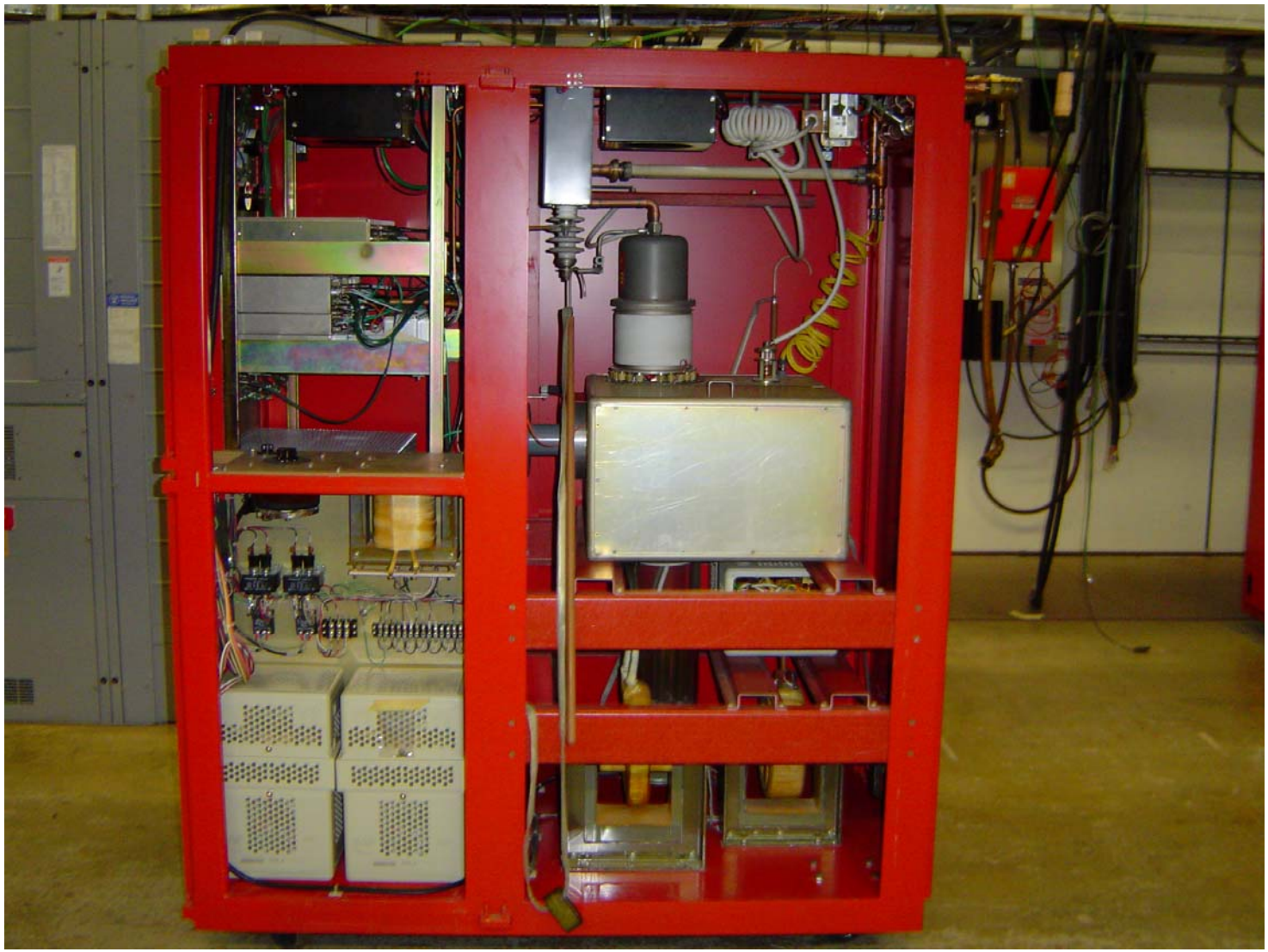
Modulators

- Design & Fabricate 20 new Series Tube Modulators
  - Required to supply 40 amps at 21 KV to 2 PA's.
  - Short R&D program is necessary for prototype.
  - Requires new higher power series tube.
  - New floating deck.
  - New grid, screen, filament supplies for series tube.
  - Additional grid, screen, filament supplies for 2nd PA.
  - Equipment gallery can tolerate slightly larger modulator footprint.

Present Series Tube Modulator



Present Series Tube Modulator



RF Sources

- **RF Power Amplifier**
  - Fabricate 20 additional 200 Kwatt Power Amplifiers.
  - Identical to present Amplifiers in MI.
- **8 Kwatt Solid State Driver Amplifier**
  - Fabricate 20 additional solid state driver amplifiers.
  - Identical to present Amplifiers in MI.
- **Local Station RF Controller**
  - Modifications to existing design required for two PA's.
  - Fabricate 20 controller chassis.

Anode Supplies

- Modify 3 existing Anode Supplies for:
  - Higher power main rectifier transformers
  - Higher power rectifier stack
  - Increased capacitor bank
  - Higher power interphase reactor
  - Higher power water resistor
  - Possible upgrade to step start 13.8 KV contactor

OR

- Build 3 more supplies – similar to existing
  - Requires civil construction for block buildings.
  - Requires procurement of all parts.

Utilities

- LCW – Requirements
  - 95 degree rf equipment system
    - Present system supplies ~ 2200 gpm to equipment.
    - Upgrades would increase flow to ~ 4100 gpm
  - 90 degree Cavity system
    - Present system supplies ~ 750 gpm
    - Upgrades would increase flow to ~ 1000 gpm
  - – Upgrade costs would be required for both systems.
- Power Distribution
  - – Sufficient 480 V power available for additional equipment.
  - – 13.8 KV feeder for Anode Power supplies may require upgraded capacity.

R&D

- Continue work to get one cavity modified with two PA's.
  - Low level measurements; cavity tuning range, spurious mode properties, dampers.
  - Implement optional rf loading to cavity by coupling power to an external water load.
- Immediately start a prototype modulator utilizing higher power series tube.
- Fabricate rf station LL RF controller for 2 PA operation.
- Test two PA cavity in MI-60 test station.
- Install in MI tunnel for testing with beam.
- Accumulate actual running time with beam.

Conclusions

- Two PA's would at best accelerate ~1.0e^{14}, ignoring stability issues.
- Work in progress to complete, document, and test a prototype two PA system.